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# Implementation of A 1280nm-1380nm Light Source for Reflective Spectrum Measurement of Biomedical Fiber Sensors

Shyh-Lin Tsao\* and Shien-Cheng Chiou

Department of Electrical Engineering

Yuan Ze University

Chung-Li, Taiwan, R.O.C

## ABSTRACT

In this paper, we present a new broadband light source covers 1280-1380nm region for application in a wavelength-division multiplexing biomedical fiber-optic Bragg grating spectra reflective sensors. We cascade two optical amplifiers for achieving the 100nm broadband light source. The cascaded two optical amplifiers are praseodymium fluoride fiber amplifier (PDFA) and multiple quantum well optical semiconductor amplifier (MQW-SOA), respectively. The optimal driving current of MQW-SOA and the optimal pumping power of PDFA are experimentally searched. We find the bandwidth can reach 100nm from 1280nm to 1380nm with driving current 50mA and pumping power 885mW of MQW-SOA and PDFA, respectively.

**Keywords:** Biomedical sensor light source, Broadband light source, Fiber sensing, Reflective Spectrum, Optical amplifier

## 1. INTRODUCTION

Fiber-optic biomedical sensors have been developed over last ten years<sup>1-3</sup>. The fiber-optic *in vivo* monitoring sensors present multi-functions. Such as PH value, pressure of O<sub>2</sub> and CO<sub>2</sub> detection. Those *in vivo* biomedical sensors need fiber-optic temperature sensors for preventing thermocouple embedded sensor contamination of blood. We reported a highly accurate temperature sensor using two fiber Bragg gratings(FBGs)<sup>4</sup> which can replace thermocouple sensor combined with the fiber-optic biomedical sensors. These FBGs sensors usually are applied in the medical apparatus by analyzing the of optical reflective spectrum<sup>5-6</sup>. Besides, optical amplifiers with the feature of broadband have the great advantage of micro- sensors for biomedical applications. The schematic diagram of the biomedical sensor system with using broadband light source we proposed is shown in Fig.1. Therefore, the intensity and spectrum range of the broadband light source is very important. In anticipation of this need, many researches have focused on the broadband and the flat gain bandwidth optical amplifier broadband light source achievement in last several years for 1.55 $\mu$ m region. Novel host materials have further broadened the optical spectral width, which can be completed with material improvement<sup>7-9</sup>. Moreover, increasing of the optical amplifier bandwidth has been proposed through cascading different optical amplifiers technologies, such as EDFA series with the Thulium-doped fiber amplifier (TDFA)<sup>10</sup> or the Raman amplifier<sup>11</sup> for 1.55 $\mu$ m region. Some promising research results of cascaded broadband optical amplifier and light source were reported<sup>12-15</sup>.

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Correspondence: E-mail:jimmy@saturn.yzu.edu.tw, Telephone: 886-3-4638800-424, Fax: 886-3-4639355

In this paper, we demonstrate a 1.3 $\mu$ m broadband light source which can be applied in wavelength-division multiplexing (WDM) biomedical fiber sensor system. We use the optical spectrum analyzer to show our experimental results which include the characteristics of WDM coupler, spontaneous emission spectra of PDFA with various pumping powers, spontaneous emission spectra of MQW-SOA with injecting current at 20°C. Finally, a new broadband light source including cascaded two optical amplifiers including PDFA and MQW-SOA is presented.

## **2. DESCRIPTION AND EXPERIMENTAL RESULTS**

The schematic diagram of our proposed 1.3 $\mu$ m broadband light source is shown in Fig.2. This optical light source include two optical amplifiers : one is PDFA, the other is MQW-SOA. We present the experimental study results in the following subsections.

### **2.1 . Measurement of WDM coupler**

In this section, we use optical spectrum analyzer to measure the transmission spectra of optical WDM coupler for combining the pump light and signal light. First, we use a white light source as input singal source and let this singal source go through the optical WDM coupler. The experimental setup is shown in Fig.3. The measured spectrum of white light source is shown in Fig.4 at first. Then, the transmission band of the optical WDM coupler at pigtail 1 is shown in Fig.5. Similarly, we measure the output pigtail 2 for the signal passband spectra shown in Fig.6. We found this optical WDM coupler can be used for combining the Nd :YLF pump light working at 1047nm and the signal light working at 1300nm.

### **2.2 . Experimental results of PDFA**

The components of the PDFA include a praseodymium-dope fluoride fiber (PDFF), a 2×2 optical WDM coupler (1047nm/1300nm) and a high power laser pumping source (1047nm). The PDFA use a high power-pumping source to achieve the population inversion. This optical WDM coupler can mix the 1047nm light coming from Nd :YLF laser and 1300nm light signal into the PDFF as a forward pumping scheme. Then, we use an optical spectrum analyzer to measure the amplified spontaneous emission spectra. The experimental setup is shown in Fig.7. With tuning the pumping power emitted from Nd :YLF laser form 0.1W to 0.8W, the amplified spontaneous emission spectra of PDFA of port 1 is shown in Fig.8. The relationship between the amplified spontaneous emission of PDFA peak output power versus the input pumping laser is shown in Fig.9. The experimental result of light coming from port 2 is shown in Fig.10 which represents the amplified spontaneous emission spectra with various pumping powers. Fig.11 shows the peak power of amplified spontaneous emission is almost linearly increased as the pumping laser power increased. When the pumping power of PDFA is provided higher than 0.885W, the lasing phenomenon may be happen because of light reflections at both fiber faces. Therefore, we know exactly how the pumping power affect the output spectrum.

### **2.3 . Experimental results of MQW-SOA**

The basic components of the MQW-SOA include a diode of optical semiconductor amplifier, a circuit of bias current source and a circuit of temperature control. The MQW-SOA we implemented can be temperature controlled. The gain of the multiple quantum well optical semiconductor amplifier can be adjusted by the driving current. The amplified spontaneous emission spectra of the MQW-SOA is measured at first. The temperature of MQW-SOA is stabilized at 20°C during spectra measurement. The experimental setup is shown in Fig.12 with tuning the injecting current of MQW-SOA from 10mA to 60mA, the amplified spontaneous emission spectra of MQW-SOA of port 1 is shown in Fig.13. Similarly, the relationship between the amplification of spontaneous emission of MQW-SOA peak power versus the driving current is shown in Fig.14. The experimental result of port 2 is shown in Fig.15. The relationship between the ASE spectrum at pigtail 2 and the driving current is shown in Fig.16. When the injecting current of the MQW-SOA is provided higher than 70mA, the lasing phenomenon may be happen because of light reflections at fiber facets. So, the injecting current tuning can vary the output spectrum distribution.

#### **2.4 Experimental results of the cascaded amplifier**

After we understand the performance of the PDFA and MQW-SOA presented in section 2.2 and section 2.3, we cascade two optical amplifiers as a broadband optical light source shown in Fig.2. The bandwidth of broadband optical amplifier of light amplification is combined with the two amplified bands of PDFA and MQW-SOA. We find the bandwidth can reach 100nm from 1280nm to 1380nm with driving current 50mA of MQW-SOA and pumping power 885mW of PDFA and MQW-SOA, respectively. The spectrum of a PDFA and a MQW-SOA compared with the spectrum of a cascade broadband optical amplifier is shown in Fig.17. Finally, the results show light spectrum can be used between 1280nm and 1380nm region.

### **3. CONCLUSION**

In summary, we have designed a broadband light source with cascading a PDFA and a MQW-SOA. The basic idea and implementation of a broadband optical amplifier covers 1280nm-1380nm is presented. The amplified spontaneous emission spectra of the cascaded PDFA and MQW-SOA are measured for optical parameters searching. The conspicuous performance of this broadband optical amplifier at wavelength 1.3  $\mu$ m band can be applied for WDM biomedical fiber sensor systems as shown in Fig.1. Moreover, the range of bandwidth and gain can be tuned by injecting current of MQW-SOA and pumping power of PDFA. This 1.3  $\mu$ m broadband light source is very useful for multi-channel broadband WDM fiber biomedical sensor systems.

### **ACKNOWLEDGMENT**

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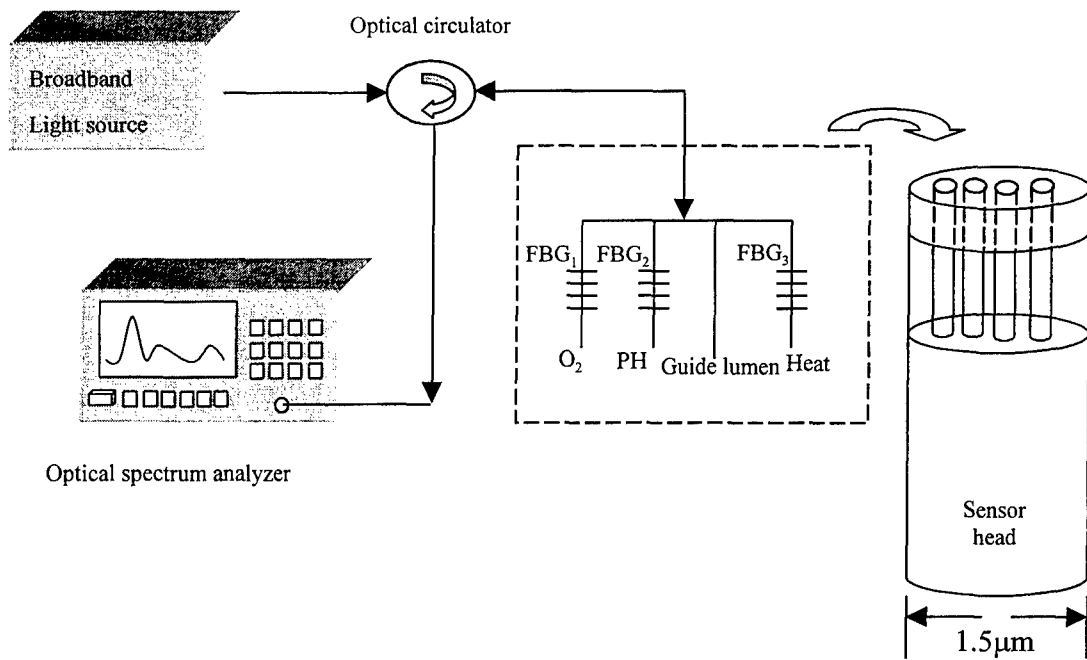


Fig.1 Schematic diagram our proposed in vivo biomedical sensor system with using a broadband light source 1280nm-1380nm

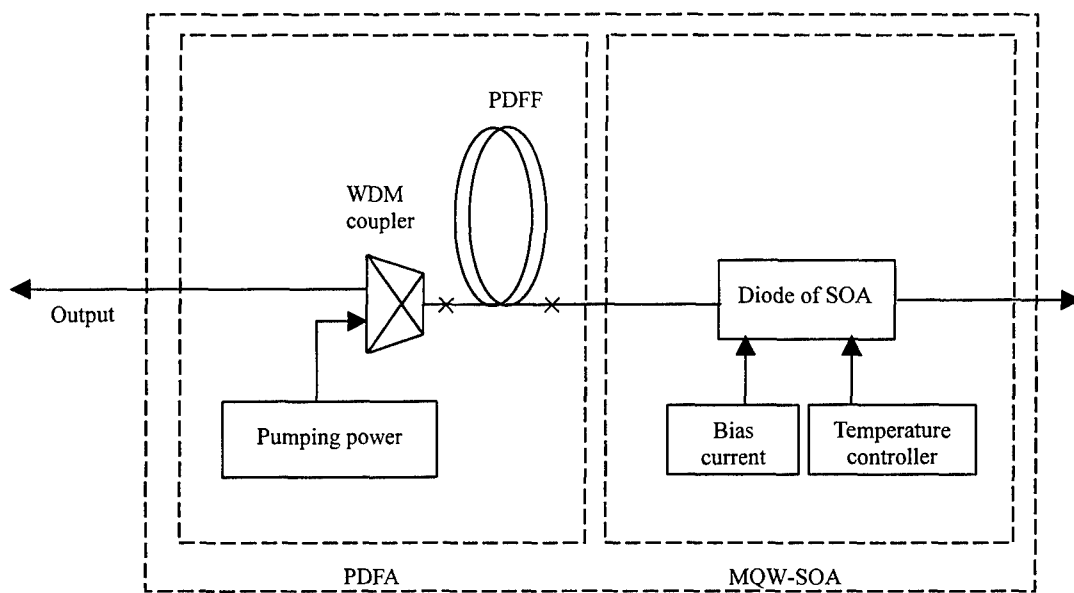


Fig.2 The schematic diagram of the proposed  $1.3\mu\text{m}$  broadband optical amplifier and light source

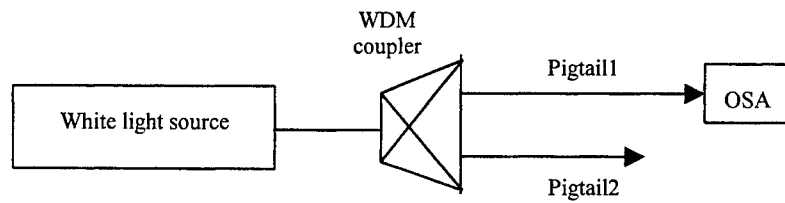


Fig.3 The experimental setup of measure the transmission spectra of WDM coupler

OSA: Optical Spectrum Analyzer

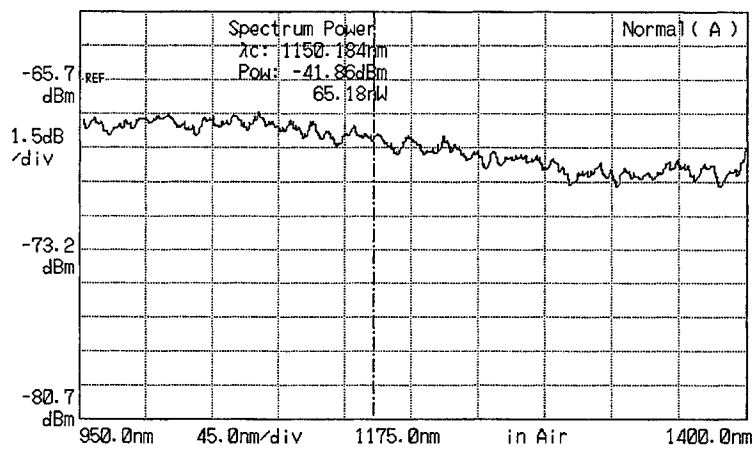


Fig.4 The measured spectrum of white light source

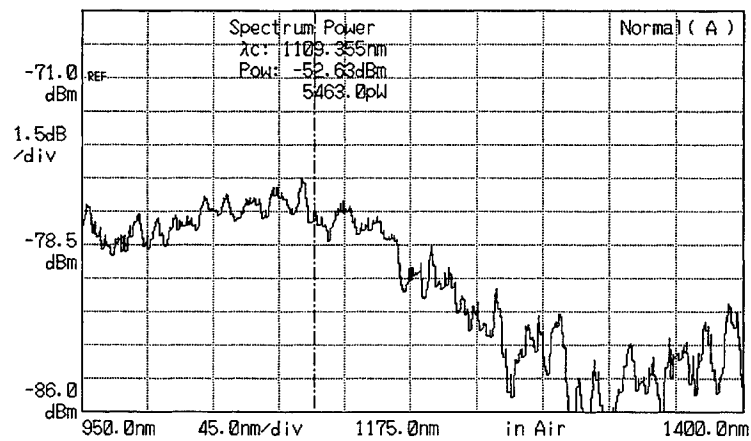


Fig.5 The transmission spectrum of WDM coupler measured at pigtail 1

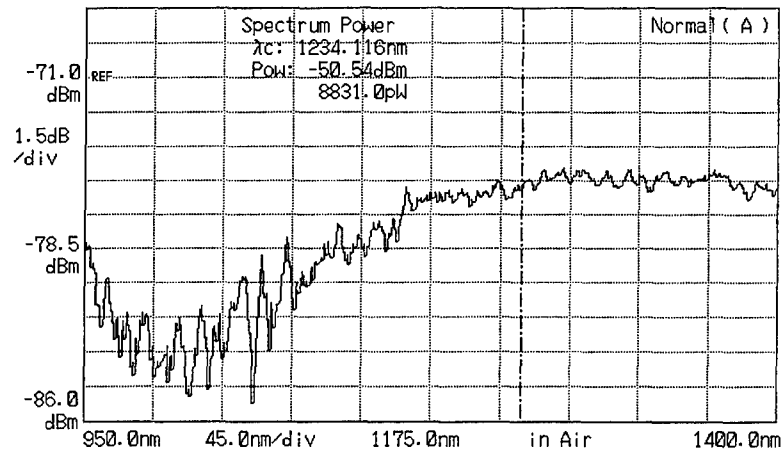


Fig.6 The transmission spectrum of WDM coupler measured at pigtail 2

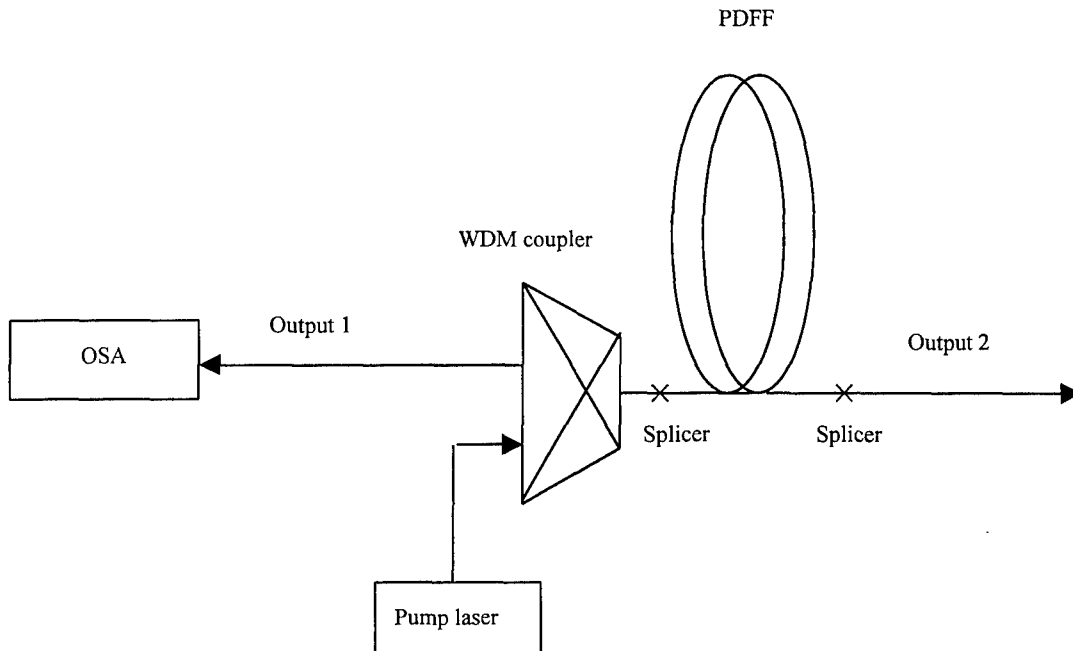


Fig.7 The experimental setup of measurement of the ASE spectrum of PDFA

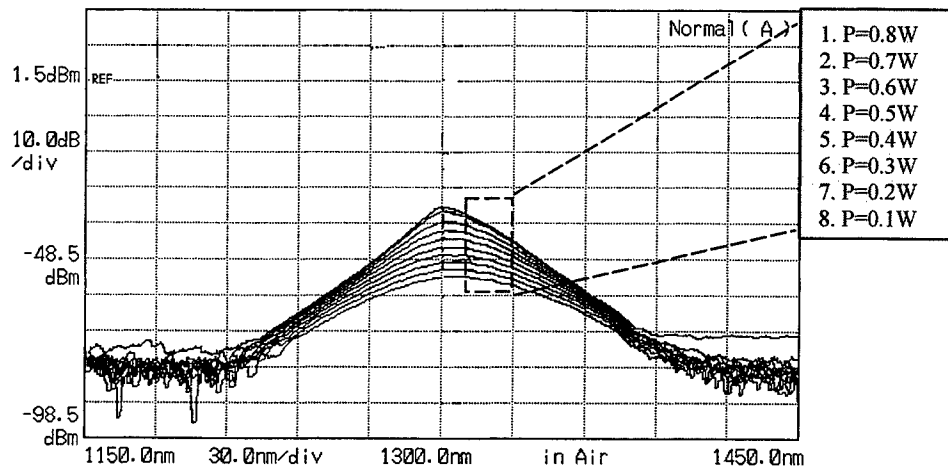


Fig.8 The ASE spectrum of praseodymium fluoride fiber amplifier at port 1

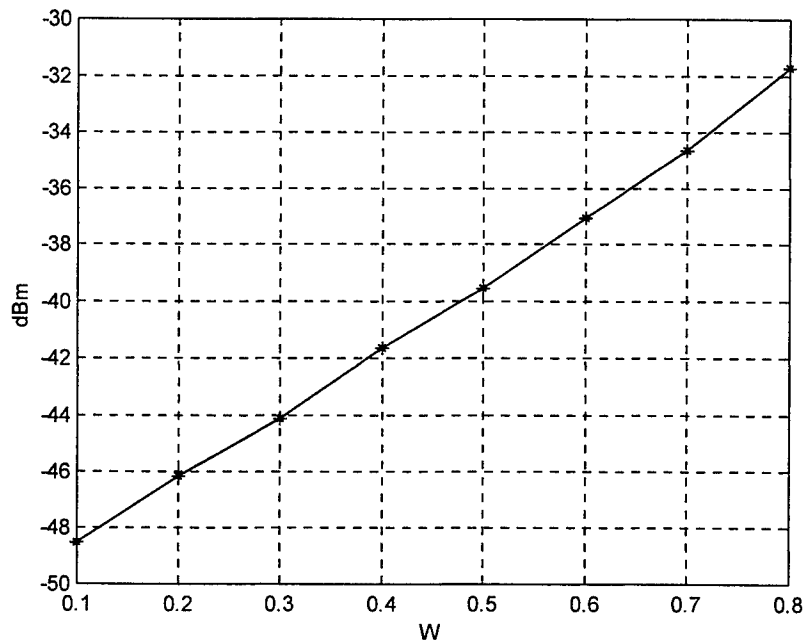


Fig.9 The output of ASE peak power at port 1 of PDFA versus the input pumping laser power

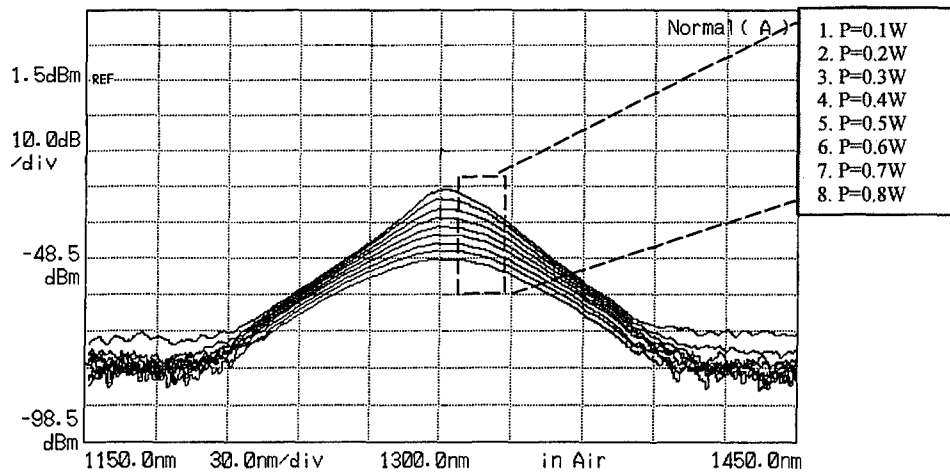


Fig.10 The ASE spectrum of PDFA at port 2

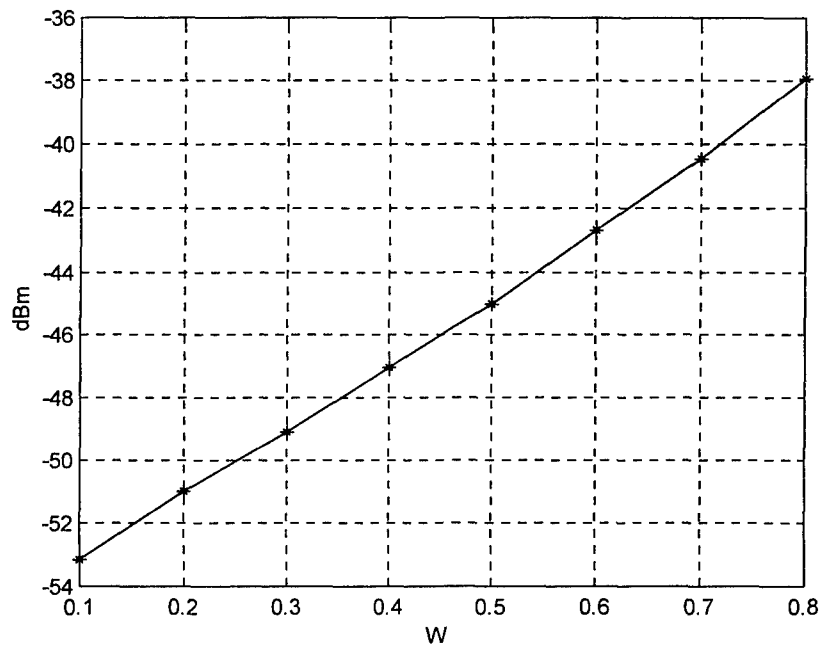


Fig.11 The relationship of PDFA peak power ASE spectrum at port 2 versus the input pumping laser power

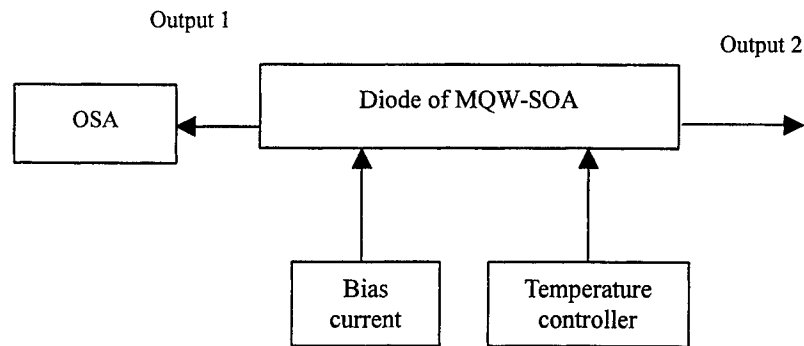


Fig.12 The experimental setup of measurement of the ASE spectrum of MQW-SOA

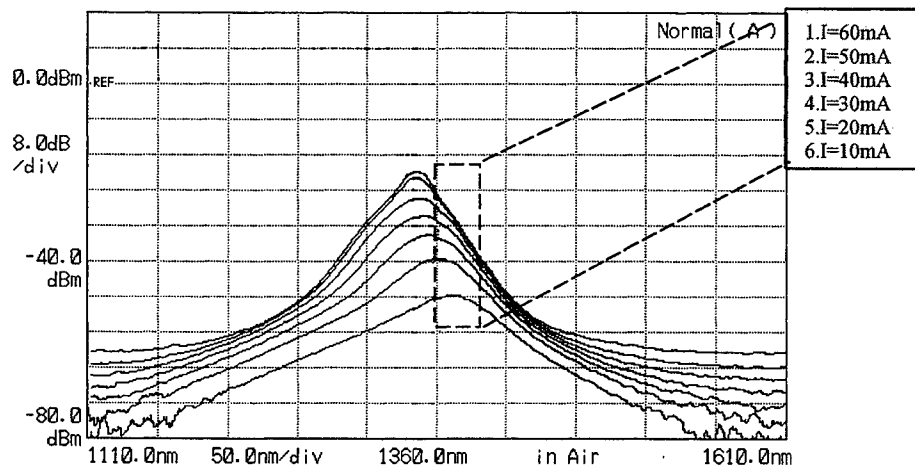


Fig.13 The ASE spectrum of MQW-SOA at port 1

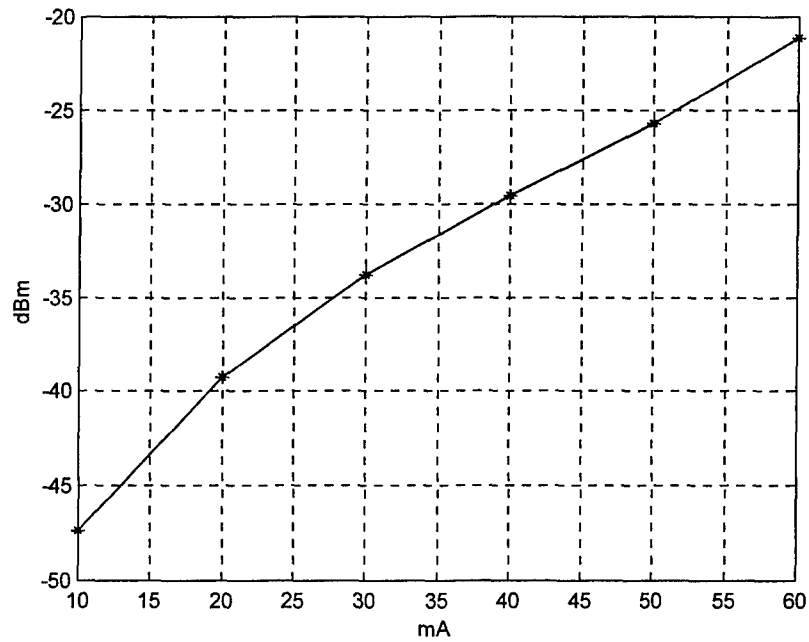


Fig.14 The relationship of MQW-SOA ASE spectrum peak power at port 1 versus the injection current

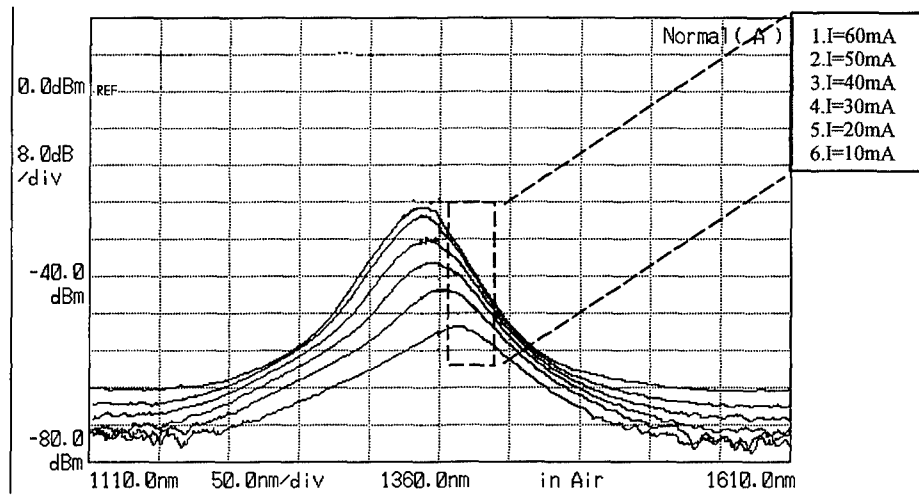


Fig.15 The ASE spectrum of MQW-SOA at port 2

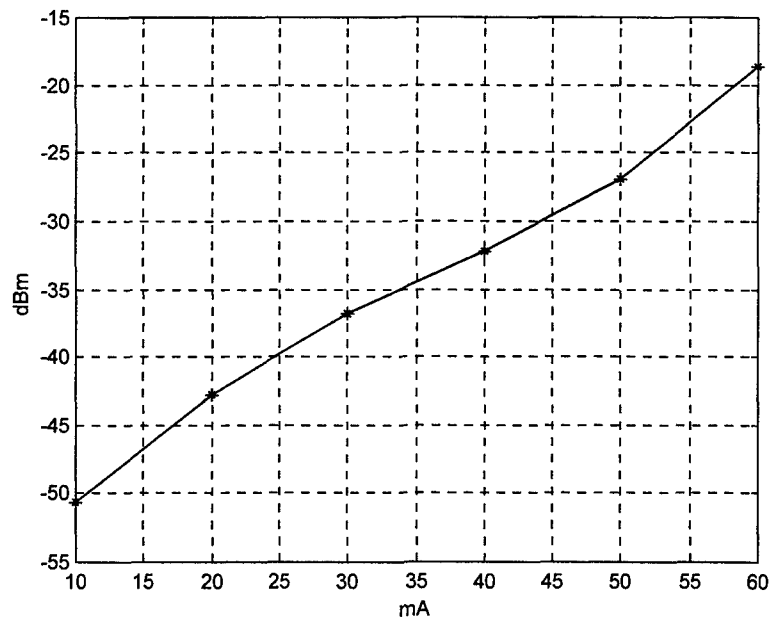


Fig.16 The relationship of MQW-SOA ASE spectrum peak power at port 2 versus the injection current

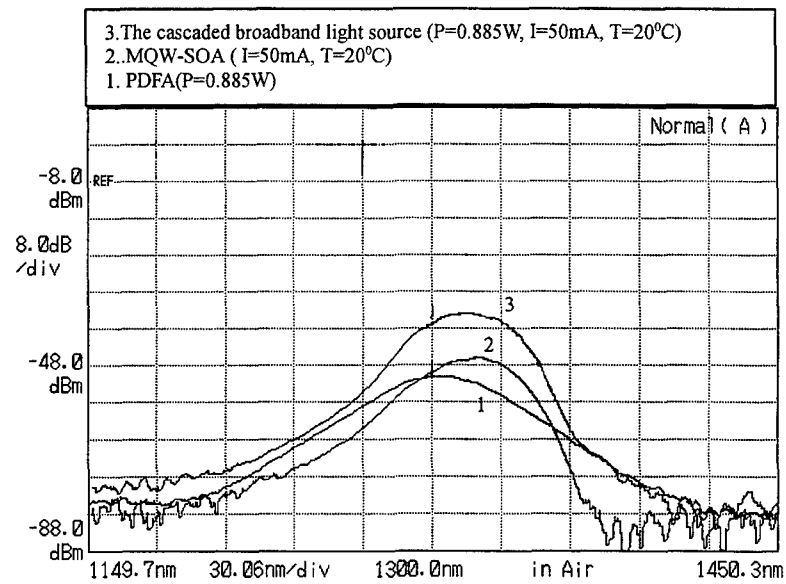


Fig.17 The spectrum of a PDFA and a MQW-SOA compare with the spectrum of a cascade broadband optical light source